MP4068

Non-isolated,TRIAC Dimmable PFC LED Driver For 120V(AC), Up to 10W LEDs

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DESCRIPTION

The MP4068 is a highly integrated TRIAC dimmable LED driver with high power factor. It precisely regulates LED current in non-isolated lighting application. Only a single winding inductor is required to realize the solution. For low-line (120VAC) application, the integrated 500V MOSFET ensures the system to withstand 500V surge test without MOV or TVS. It features MPS's proprietary hybrid operation mode which is designed to achieve good dimming performance. The MP4068 is specifically designed for low-line input (120VAC), TRIAC-dimmable LED lighting applications, especially for the low cost and small form factor applications.

The accurate output LED current is achieved by an internal averaging current feedback loop. An internal high voltage regulator makes the MP4068 start-up quickly without a perceptible delay. The power de-rating at high temperature makes the system flicker-free when the ambient temperature is high.

The MP4068 features various protections such as VCC Under Voltage Lockout (UVLO), Over Voltage Protection and Short Circuit Protection. All of these features make MP4068 an ideal solution for simple, off-line and non-isolated TRIAC dimmable LED lighting applications.

The MP4068 is available in the SOIC8-7A and SOIC-8 EP packages.

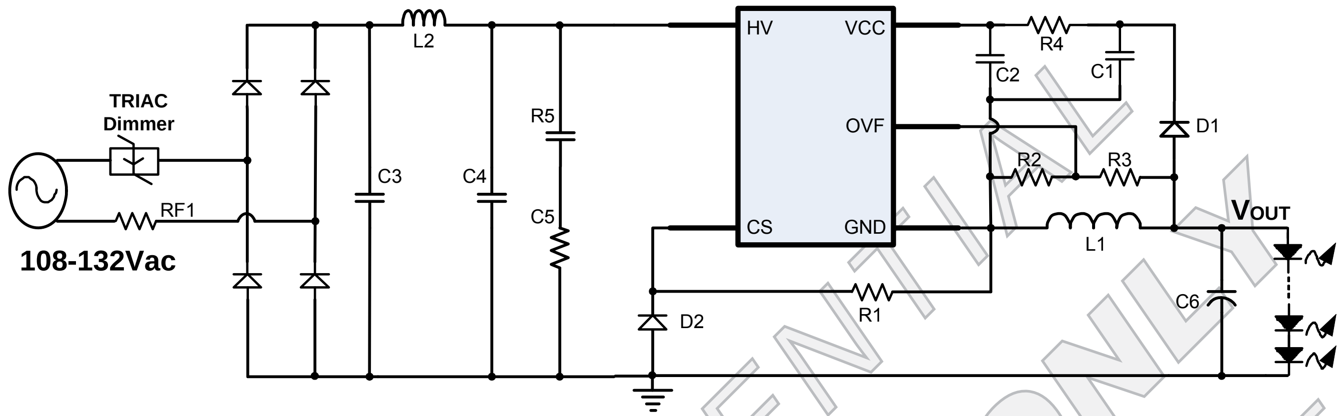
FEATURES

- Excellent TRIAC Dimming Performance
- Lowest Cost BOM
- Constant Current LED Driver
- 500V MOSFET Integrated
- Internal HV Fast Start-Up
- Single Winding Inductor
- High Power Factor(>0.7)
- Good LED Current Accuracy
- Supports Buck/Buck-Boost Topology
- LED Current Foldback at High Temperature
- Thermal Shutdown (Auto Restart with Hysteresis)
- VCC Under Voltage Lockout with Hysteresis (UVLO)
- Programmable Over Voltage Protection
- Output Short Circuit Protection
- SOIC8-7A/SOIC-8 EP Package Available

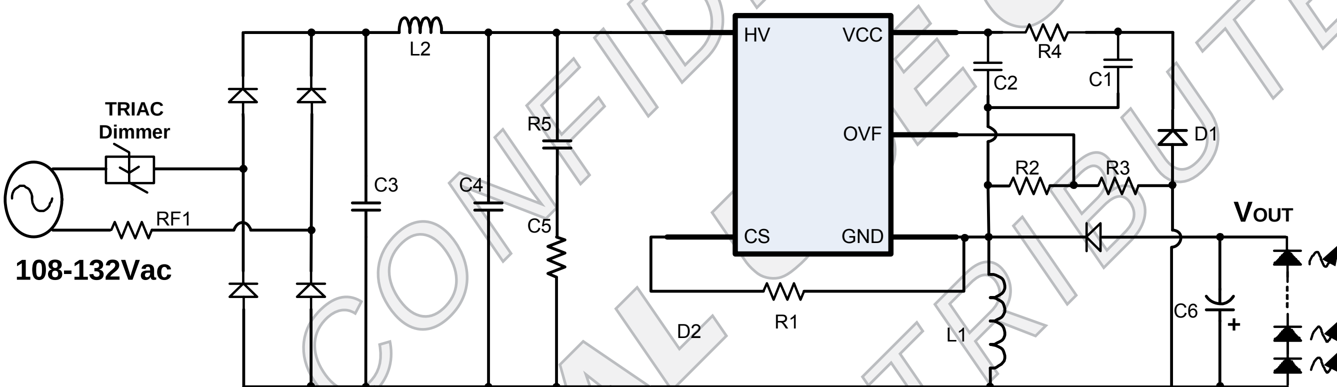
APPLICATIONS

- 120V(AC), Up to 10W LED Lighting
- Residential and Commercial Lighting
- TRIAC Dimmible LED Lighting, A19, GU10, PAR Lamps

TYPICAL APPLICATION (BUCK)



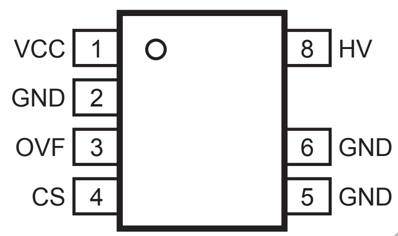
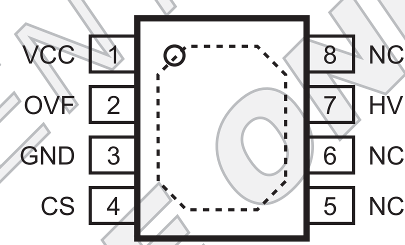
TYPICAL APPLICATION (BUCK-BOOST)



ORDERING INFORMATION

Part Number	Package	Top Marking

PACKAGE REFERENCE

TOP VIEW	TOP VIEW
	
SOIC8-7A	**SOIC-8 EP**

ABSOLUTE MAXIMUM RATINGS (1)

HV to CS .... -0.3V to 500V
VCC, CS to GND .... -0.3V to6.5V
OVF to GND .... -0.7V to 6.5V
Source Current on OVF 4mA
Continuous Power Dissipation (T_A = +25°C) **(2)**
SOIC8-7A 1.6W
SOIC-8 EP 2.6W
Junction Temperature .... 150°C
Lead Temperature .... 260°C
Storage Temperature .... -60°C to +150°C
ESD Capability Human Body Mode 2.0kV
ESD Capability Machine Mode 200V

Recommended Operating Conditions (3)

Operating VCC Range .... 4.5V to 4.7V

Thermal Resistance (4)

	θ_{JA}	θ_{JC}	
SOIC8-7A	76	35	°C/W
SOIC-8 EP	48	10	°C/W

Notes:

1) Exceeding these ratings may damage the device.
2) The maximum allowable power dissipation is a function of the maximum junction temperature T_J (MAX), the junction-to-ambient thermal resistance θ_{JA}, and the ambient temperature T_A. The maximum allowable continuous power dissipation at any ambient temperature is calculated by P_D (MAX) = (T_J (MAX)-T_A)/θ_{JA}. Exceeding the maximum allowable power dissipation will cause excessive die temperature, and the regulator will go into thermal shutdown. Internal thermal shutdown circuitry protects the device from permanent damage.
3) The device is not guaranteed to function outside of its operating conditions.
4) Measured on JESD51-7, 4-layer PCB.

ELECTRICAL CHARACTERISTICS

Typical values are VCC =4.7V, T_J = 25°C, unless otherwise noted.

Minimum and maximum values are at VCC =4.7V, T_J = -40°C to +125°C, unless otherwise noted, guaranteed by characterization.

Parameter	Symbol	Condition	Min	Typ	Max	Units
Start-Up Current Source (HV)						
Internal Regulator Supply Current	$I_{REGULATOR}$	VCC=4.5V;V_{HV}=100V	4.5	5	6	mA
Leakage Current from HV	I_{HV_LKG}	VCC=6V;V_{HV}=400V		14	20	μA
Supply Voltage Management (VCC)						
VCC Increasing Level at Which The Internal Regulator Turn-Off	VCC_{OFF}		4.45	4.65	4.85	V
VCC Decreasing Level at Which The Internal Regulator Turn-On	VCC_{ON}		4.20	4.40	4.60	V
VCC Hysteresis between Regulator ON/OFF	VCC_{HYS}		0.18	0.24	0.3	V
VCC Decreasing level at Which The IC Stops Working	VCC_{STOP}		3.17	3.27	3.37	V
VCC Hysteresis between Regulator OFF to VCC Stops	$VCC_{HYS-STOP}$		1.23	1.38	1.52	V
VCC Decreasing Level at Which The Protection Phase Ends	VCC_{PRO}		2.10	2.35	2.60	V
Internal IC Consumption	I_{CC}	VCC=4.6V, fsw=33kHz, D=84%		350	400	uA
Internal IC Consumption, Latch Off Phase	I_{CC_LATCH}	VCC=5V		18	21	μA
Internal MOSFET (HV to CS)						
Break Down Voltage	V_{BR}		500			V
On-State Resistance	R_{ON}	I_{HV}=10mA, T_J =25°C		7	10	Ω
		VCC= VCC_{STOP} +50mV, I_D=10mA, T_J =25°C		7	10	Ω
Current Sampling Management (CS)						
Peak Current Limit	V_{LIMIT}		0.42	0.45	0.49	V
Leading Edge Blanking	t_{LEB}			200		ns
Feedback Threshold to Turn On MOSFET	V_{FB}		0.188	0.194	0.200	V
Minimum OFF Time Limitation	t_{OFF_MIN}		5.7	6	6.3	μs
Maximum ON Time Limitation	t_{ON_MAX}		7.6	8	8.4	μs

ELECTRICAL CHARACTERISTICS *(continued)*

Typical values are VCC =4.7V, T_J = 25°C, unless otherwise noted.

Minimum and maximum values are at VCC =4.7V, T_J = -40°C to +125°C, unless otherwise noted, guaranteed by characterization.

Parameter	Symbol	Condition	Min	Typ	Max	Units
Protection input (PRO)						
Threshold to Trigger OVP	V_{OVP}		1.9	2.0	2.1	V
Time Constraint on OVP Comparator	t_{OVP}			21	28	µs
Thermal Protection						
Power De-Rating Threshold (5)	T_{START}			145		°C
Thermal Shutdown Threshold (5)	T_{SD}			160		°C
Thermal Shutdown Recovery Hysteresis (5)	T_{HYS}			70		°C

Notes:
5) Guaranteed by characterization.

TYPICAL CHARACTERISTICS

TBD

TYPICAL CHARACTERISTICS *(continued)*

TBD

TYPICAL PERFORMANCE CHARACTERISTICS

Performance waveforms are tested on the evaluation board of the Design Example section.
V_{IN} = 120VAC, V_{OUT} = 50V, I_{OUT}=160mA, L = 1mH, T_A = 25°C, unless otherwise noted.

TBD

TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

Performance waveforms are tested on the evaluation board of the Design Example section.
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TBD

PIN FUNCTIONS

Pin # SOIC8-7A	Pin # SOIC-8 EP	Name	Description
1	1	VCC	Power Supply. Supply power for all the control circuits. Typically connect this PIN to an external 2.2uF capacitor.
2,5,6	3	GND	Virtual Ground of the IC
3	2	OVF	Output Voltage feedback. The over voltage condition is detected on this PIN. When the voltage on OVF exceeds the V_{OVP}, after a blanking time, the OVP is triggered, and the chip shut down.
4	4	CS	Current Sense of the internal power MOSFET. Connect a resistor from this PIN to GND to sense the current through the inductor. When the voltage on this PIN exceeds 0.45V, the internal MOSFET is turned off. But if the turning on time exceeds the maximum on time 8us, the internal MOSFET will be turned off even though the voltage on this PIN have not reach 0.45V.
8	7	HV	High Voltage input of the internal power MOSFET. It is also the input of internal high voltage current source.
	5,6,8	NC	Not connected.

FUNCTION BLOCK DIAGRAM

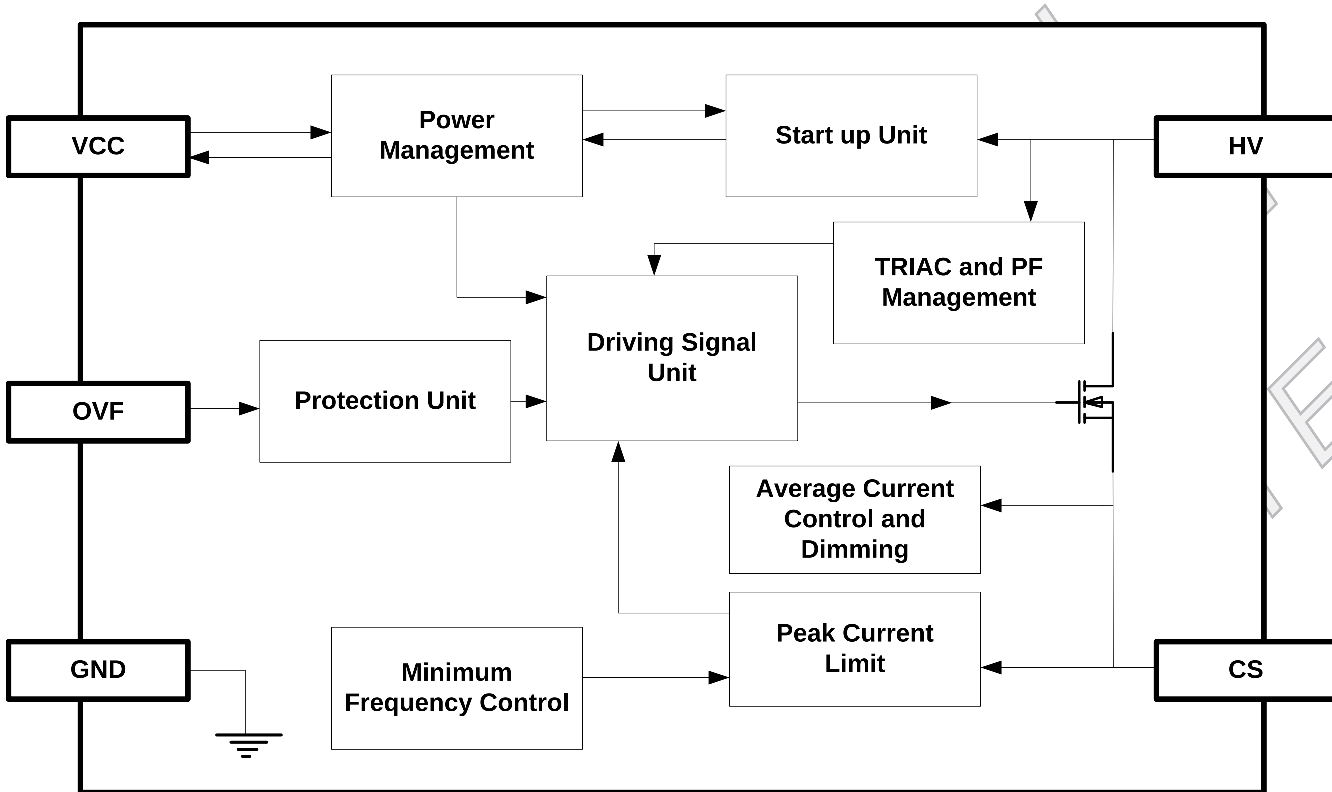


Figure 1: Functional Block Diagram

OPERATION

The MP4068 is a highly integrated and cost-effective TRIAC-dimmable LED driver with high power factor. The minimum number of external components makes the MP4068 a competitive IC in low-line (120VAC) input, non-isolated applications, especially for small form factor applications. The hybrid operation mode is used to achieve both good dimming performance and accurate output current. The power factor is higher than 0.7 in most applications to eliminate the harmonic pollution on AC line. The integrated high voltage regulator enable fast start up without any perceptible delay. The power de-rating function at high temperature protects the IC from thermal damage.

Hybrid Operation Mode

In order to achieve smooth TRIAC dimming performance, MP4068 implements an MPS proprietary hybrid operation mode in which the IC self-adjusts the internal PWM control mode between CCM and DCM during different times of the AC cycle. The hybrid operation mode actively maintains the latching current and holding current of the leading edge TRIAC. This mode also enables good power factor.

The other use of the hybrid operation is for the small dimming duty condition. The IC works in CCM during the whole dimming on time when the dimmer is tuned to a small dimming duty. The higher and smooth input current helps to achieve excellent dimming performance.

Power supply

The IC is self supplied by the internal high voltage regulator which is drawn from the Drain pin. The IC starts switching and the internal high voltage regulator turns off as soon as the voltage on pin V_{CC} reaches VCC_{OFF} (4.65V, typical). When the voltage on Pin VCC decreases below VCC_{ON} (4.4V, typical), the internal high voltage regulator turns on again to charge the external V_{CC} capacitor. A small capacitor such as several µF capacitor is recommended. In TRIAC dimming application, the internal HV regulator works only when the dimmer is on, and can not afford enough power supply for chip, so an external charging circuit is recommended, shown in Figure 2.

When the voltage on Pin V_{CC} drops blow VCC_{STOP} (3.27V, typical), the IC stops working, the internal high voltage regulator recharges the Vcc capacitor.

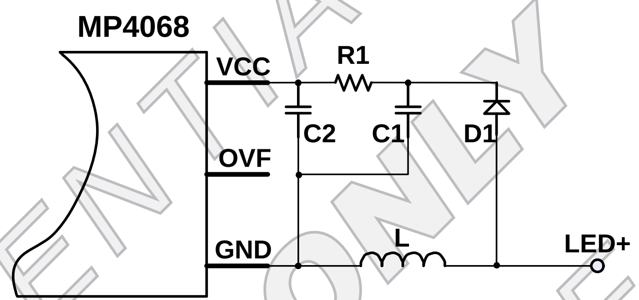


Figure 2: VCC Charging Circuit

When OVP happens, the MP4068 stops working and an 18µA internal current source discharges the Vcc capacitor. After the V_{CC} drops below VCC_{PRO} (2.37V, typical), the internal high voltage regulator recharges the V_{CC} capacitor again. The restart time can be calculated by the following equation,

$$t_{restart} = C_{Vcc} \times \frac{Vcc - 2.37V}{18\mu A} + C_{Vcc} \times \frac{4.65V - 2.37V}{5mA}$$

Figure 3 shows the typical waveform with VCC under voltage lock out.

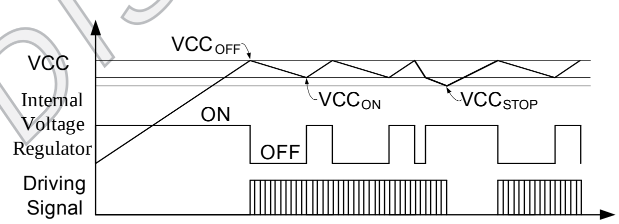


Figure 3: VCC Under-Voltage Lock Out (UVLO)

Constant Current Operation

The MP4068 is a highly integrated driver, the internal feedback logic responds to the internal sample and hold circuit to achieve constant output current regulation. The voltage of the internal sampling capacitor (V_{FB}) is compared to the internal reference 0.194V, when the sampling capacitor voltage (V_{FB}) falls below the reference voltage, which indicates insufficient output current, the integrated MOSFET is turned ON. The ON period is determined by the peak current limit. After the ON period elapses, the integrated MOSFET is turned OFF. The detailed operation is shown as Figure 4.

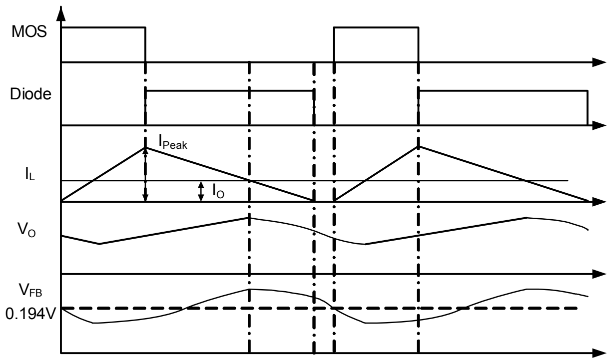


Figure 4: V_{FB} vs I_{OUT}

Thus by monitoring the internal sampling capacitor voltage, the output current can be regulated and the output current is determined by the following equation:

$$I_O = \frac{0.194V}{R1}$$

The peak current can be obtained as follow:

$$I_{Peak} = \frac{0.45V}{R1}$$

R1 is the sense resistor.

Minimum Operating Frequency Limit

The MP4068 incorporates minimum operating frequency (22kHz) to eliminate the audible noise when frequency is less than 20kHz.

When operating frequency is less than 22kHz, the internal peak current regulator will decrease the peak current value to keep the operating frequency constant about 22kHz.

Minimum Off Time Limit

A minimum off time limit is implemented. During the normal operation, the minimum off time limit is 6us, and during the start up period, the minimum off time limit is shortened gradually from 18.8μs, 9.4μs to 4.7μs (Shown as Figure 5). Each minimum off time keeps 128 switching cycle. This soft start function enables safe start-up.

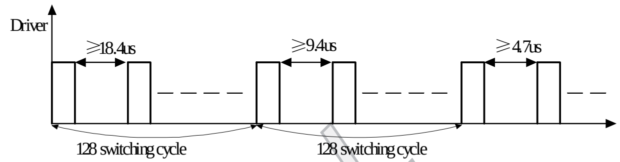


Figure 5: t_{minoff} at start-up

Thermal Protection

To prevent the IC and system from any lethal thermal damage, MP4068 reduces the reference to decrease the output current, to limit the temperature rising speed of the IC, when the junction temperature exceeds 145°C. Typically the output current drops to 40% when the IC temperature rises to 160°C. Once the junction temperature exceeds 160°C, the MP4068 will shut down the switching cycle. As soon as the junction temperature drops below 100°C, the power supply resumes operation. During the thermal shutdown condition, the V_{CC} is discharged to VCC_{PRO}, and then is re-charged by the internal high voltage regulator.

Over Voltage Protection

When MOSFET turns off, if the OVF pin voltage (V_{OVF}) is higher than the over voltage protection voltage of the IC (V_{OVP}), MP4068 stops working and a re-start cycle begins. When OVP happens, the chip works in hiccup mode. MP4068 monitors the OVF pin voltage continuously and the VCC voltage discharges and recharges repeatedly. MP4068 resumes work until the fault disappears.

Short Circuit Protection

When the LED short circuit occurs, the switching off time extends. Due to the minimum operating frequency limit, the IC can automatically reduce the switching frequency and achieve close loop control. Then the output power at this condition is limited at a safe range. The MP4068 resumes work at normal operation once the short circuit releases.

Leading Edge Blanking

There are parasitic capacitances in the circuit which can cause high current spike during the turn-on of the internal MOSFET. In order to avoid the premature termination of the switching pulse, an internal Leading Edge Blanking (LEB) unit is employed. During the blanking time, the current comparator is disabled and blocked from turning off the internal MOSFET. Figure 6 shows the leading edge blanking.

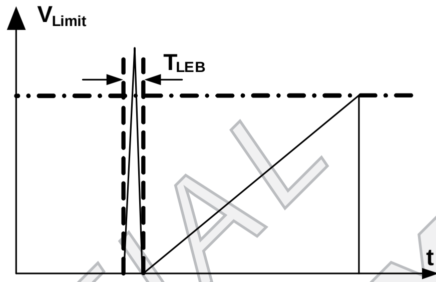


Figure 6: Leading Edge Blanking (LEB)

APPLICATION INFORMATIO

Component Selection

Inductor

The MP4068 has a minimum off time limit. The inductor current ripple at CCM is determined by the inductor value and the minimum off time limit. The current ripple is limited to 30% to get a tradeoff between the PF and dimming performance. The inductance value can be obtained as follows:

$$L = \frac{V_O * t_{OFF\_MIN}}{0.3 * I_{peak}}$$

If the inductance value is too large, the current ripple will be small, so the input current will be large. It is useful for TRIAC dimming. But the power factor will be bad at this condition. So a tradeoff must be made here.

Freewheeling Diode

The diode should have a maximum reverse voltage rating which is greater than the maximum input voltage. The current rating of diode is determined by the output current which should be larger than 1.5~2 times output current.

Slow diodes cause excessive leading edge current spikes during start-up which is not acceptable. Long reverse recovery time of freewheeling diode can also affect the efficiency and the circuit operation. So ultrafast diode (t_{rr}<75ns) such as WUGC10JH or ES1G are recommended.

Over Voltage Protection Point set

Feedback resistor is used to detect the over voltage condition. Figure 7 shows the feedback resistors connection.

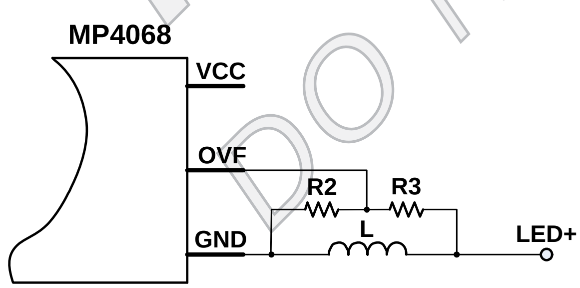


Figure 7: Feedback resistor connection

The MP4068 is integrated with over voltage protection and the maximum output voltage when over voltage protection is triggered can be designed as the following equation:.

$$V_{O\_MAX} = V_{OVP} * \frac{R2 + R3}{R2} - V_D$$

V_D is the freewheeling diode forward voltage drop.

The upper feedback resistor (R3) is suggested to be larger than 100kΩ to avoid the efficiency reduction in application. And the 1% tolerance type is recommended to use as feedback resistor to achieve accurate protection.

Dummy Load

The dummy load is used to consume the power transferred to output capacitor when over voltage protection happened. The IC works on hiccup mode without any power consumption.

Normally less than 1mA dummy load is suggested which will not deteriorate the system efficiency but can guarantee the normal over voltage protection.

Output Power V-I Curve

The thermal performance limits the output power of the MP4068 in very small size LED application. The maximum output power can not be defined as one value simply. It is affected by the output voltage and output current specification.

Figure 8 shows the reference V-I curve in low line input under following assumed conditions:

1. Buck topology.
2. Around 30kHz working frequency.
3. The output current drops to 90% at 90℃ ambient temperature.
4. Not trigger the thermal shutdown at 105℃ Ambient temperature

TBD

Figure 8: Low line input V-I curve

(108VAC - 132VAC)

Layout Guide

PCB layout is very important to achieve reliable operation, good EMI and good thermal performance especially in very small size LED application. The following shows some layout recommendations.

1. The loop formed between the MP4068, inductor, freewheeling diode and output capacitor should be kept as small as possible for better EMI.
2. Put the AC input far away from the switching nodes to minimize the noise coupling that may bypass the input filter.
3. The VCC pin capacitor should be located physically close to the IC and GND.
4. Put the feedback resistor next to the OVP pin as possible to minimize the feedback sampling loop to minimize the noise coupling route.
5. In the buck topology, since the MP4068 S pin and GND pin are switching nodes, the copper area connected to these pins should be small to improve EMI performance. But the GND pin is also used as a heat-sink, a large copper area GND can improve the thermal performance. So you must make a tradeoff between EMI and thermal.

Figure 9 shows a sample layout.

TBD

Top Layer

TBD

Bottom Layer

Figure 9: PCB Layout

Design Example

Below is a design example following the application guidelines based on these specifications:

Table 1: Design Example

V_{IN}	108Vac~132Vac
V_{OUT}	50V
I_{OUT}	160mA

Figure 10 shows the detailed application schematic. This circuit is used for the typical performance and circuit waveforms. For more device applications, please refer to the related evaluation board datasheets.

TYPICAL APPLICATION CIRCUITS

Figure 10 shows a typical application example of a 50V, 160mA non-isolated buck topology power supply using the MP4068.

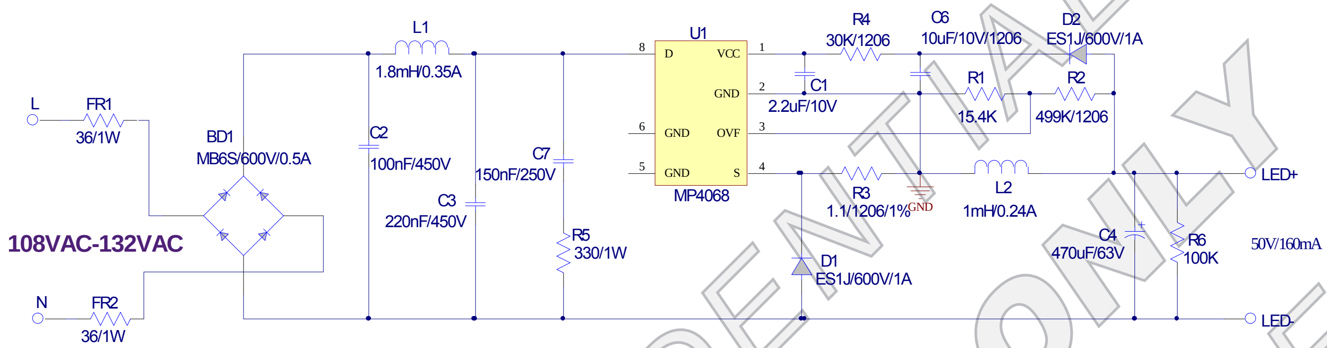
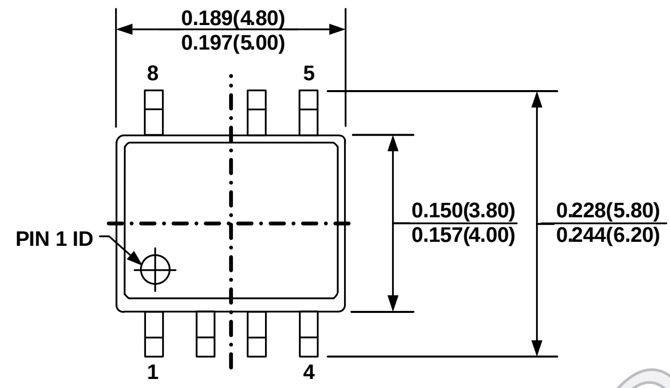


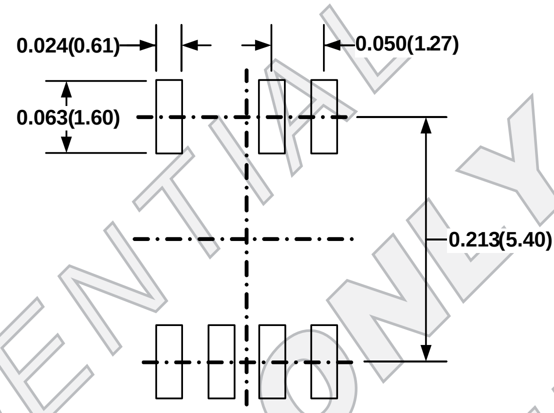
Figure 10: Typical Buck Converter Application

PACKAGE INFORMATION

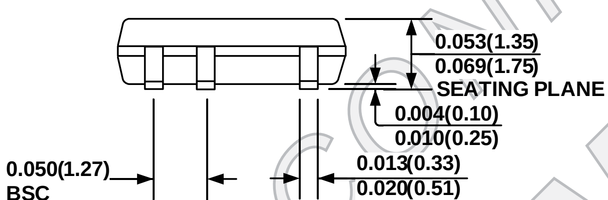
SOIC8-7A



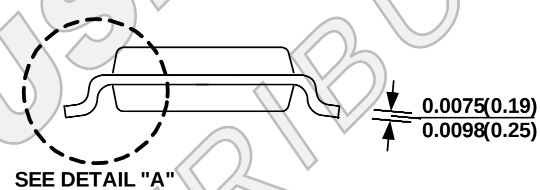
TOP VIEW



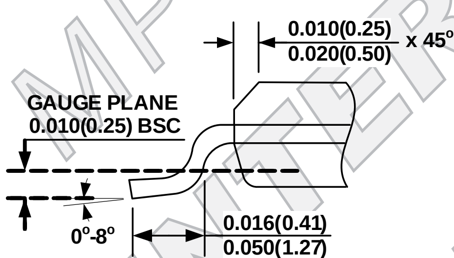
RECOMMENDED LAND PATTERN



FRONT VIEW



SIDE VIEW



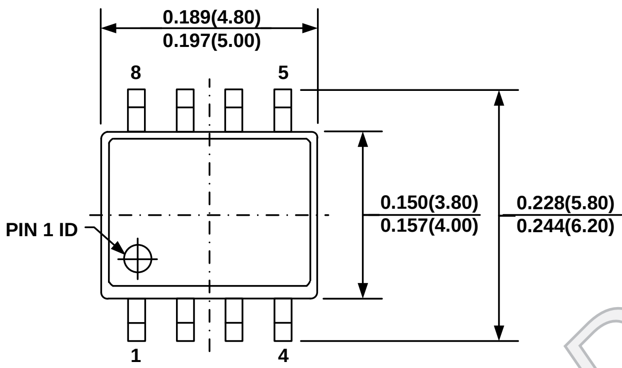
DETAIL "A"

NOTE:

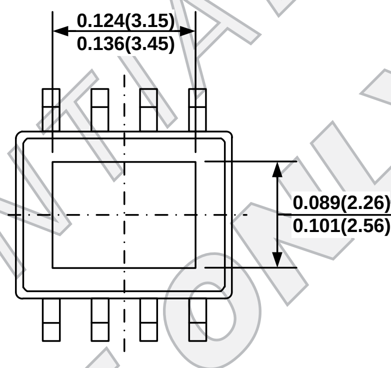
1) CONTROL DIMENSION IS IN INCHES. DIMENSION IN BRACKET IS IN MILLIMETERS.
2) PACKAGE LENGTH DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS.
3) PACKAGE WIDTH DOES NOT INCLUDE INTERLEAD FLASH OR PROTRUSIONS.
4) LEAD COPLANARITY (BOTTOM OF LEADS AFTER FORMING) SHALL BE 0.004" INCHES MAX.
5) JEDEC REFERENCE IS MS-012.
6) DRAWING IS NOT TO SCALE.

PACKAGE INFORMATION *(continued)*

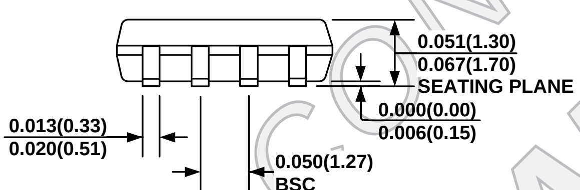
SOIC-8 EP



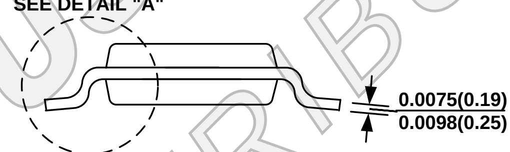
TOP VIEW



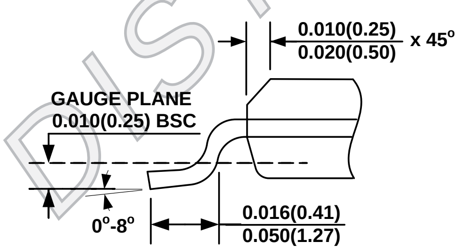
BOTTOM VIEW



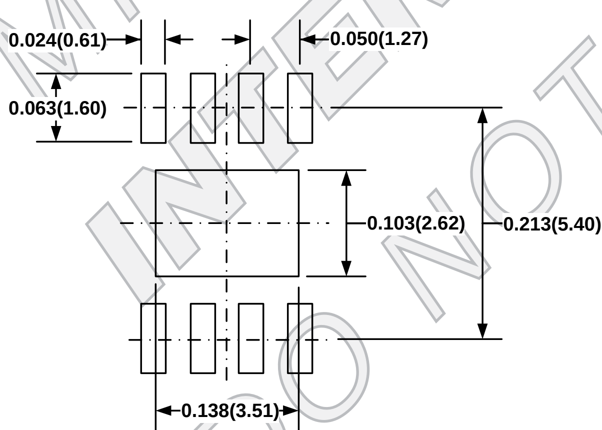
FRONT VIEW



SIDE VIEW



DETAIL "A"



RECOMMENDED LAND PATTERN

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4) LEAD COPLANARITY (BOTTOM OF LEADS AFTER FORMING) SHALL BE 0.004" INCHES MAX.
5) DRAWING CONFORMS TO JEDEC MS-012, VARIATION BA.
6) DRAWING IS NOT TO SCALE.